1997

NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

SOFTWARE PRODUCTS FOR TEMPERATURE DATA REDUCTION OF PLATINUM RESISTANCE THERMOMETERS (PRT)

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Introduction

The main objective of this project is to create user-friendly personal computer (PC) software for reduction/analysis of platinum resistance thermometer (PRT) data.

The Callendar-Van Dusen Equation

The Callendar-Van Dusen equation is the accepted method (International Temperature Scale - 1927, ITS-27, and International Practical Temperature Scale - 1948, IPTS-48) for calculating resistance, *R*, given a temperature, *t*, for PRTs.

The general expression for the Callendar-Van Dusen equation is: (Rosemount Report 68023F)

$$R_t = R_0\left\{1+\alpha\left[t-\delta\left(\frac{t}{100}\right)\left(\frac{t}{100}-1\right)-\beta\left(\frac{t}{100}-1\right)\left(\frac{t}{100}\right)^3\right]\right\} \qquad (1)$$

where: R_t = resistance at temperature t (ohms)
R_0 = resistance at 0°C
t = temperature, °C
α, δ, and β are calibration constants

For temperatures above 0°C, $\beta = 0$, and equation (1) becomes

$$R_t = R_0\left\{1+\alpha\left[t-\delta\left(\frac{t}{100}\right)\left(\frac{t}{100}-1\right)\right]\right\} \qquad (2)$$

and this equation is known as the **Callendar Equation**.

When t_1 = 100°C then, from equation (2)

$$\alpha = \frac{R_{100}-R_0}{100R_0} \qquad (3)$$

where α is the temperature coefficient over the range 0°C to 100°C.

Knowing the value of α, δ can be calculated from a third calibration point, t_2 as follows:

$$\delta = \frac{t_2 - \left(R_{t_2}/R_0 - 1\right)/\alpha}{\left(t_2 - 100\right)\left(t_2/100 - 1\right)} \qquad (4)$$

Finally, knowing the value of α and δ, β can be calculated from a fourth calibration point, t_2, (below 0°C) as follows:

$$\beta = \frac{R_0\left(1 + \alpha t_3\right) - R_{t_3}}{R_0\alpha\left(t_3/100 - 1\right)\left(t_3/100\right)^3} - \frac{\delta}{\left(t_3/100\right)^2} \qquad (5)$$

For efficient computation, however, a method that relates α, β, and δ is desirable. For this reason, constants **A**, **B**, and **C** can be computed as follows:

$$A = \alpha(1 + \delta/100) \qquad (6)$$

$$B = -\alpha\delta/10^4 \qquad (7)$$

$$C = -\alpha\beta/10^8 \qquad (8)$$

or

$$\alpha = A + 100B \qquad (9)$$

$$\delta = -10^4B/(A + 100B) = 10^4B/\alpha \qquad (10)$$

$$\beta = -10^8C/(A + 100B) = -10^8C/\alpha \qquad (11)$$

With these constants, equation (1) may be computed with

$$W = 1 + At + Bt^2 + Ct^3(t-100) \qquad (12)$$

where W is the resistance ratio R_t/R_0 and C = 0 when t > 0°C

This approach allows the calibration to use three temperature points in addition to 0°C. One is a low temperature < 150°C, another is a high temperature > 250°C, and a third temperature ≅ 100°C. The constants A, B, and C may be computed by solution of the simultaneous equations:

$$W_1 = 1 + At_1 + Bt_1^2 \quad \text{for } (T_1 > 0°C) \tag{13}$$

$$W_2 = 1 + At_2 + Bt_2^2 \quad \text{for } (T_2 > 0°C) \tag{14}$$

$$W_3 = 1 + At_3 + Bt_3^2 + Ct_3^3(t_3 - 100) \quad \text{for } (t_3 < 0°C) \tag{15}$$

The solution set is as follows:

$$A = \frac{\left(W_2 - 1\right)t_1/t_2 - \left(W_1 - 1\right)t_2/t_1}{t_1 - t_2} \tag{16}$$

$$B = \frac{\left(W_2 - 1\right)/t_2 - \left(W_1 - 1\right)/t_1}{t_2 - t_1} \tag{17}$$

$$C = \frac{W_3 - 1 - At_3 - Bt_3^2}{t_3^3\left(t_3 - 100\right)} \tag{18}$$

<u>Solving for Temperature</u>

Equation (12) must be solved for temperature, *t*, to easily compute the temperature represented by a measured resistance. For temperatures above 0°C only, the solution is as follows:

$$t = \frac{\sqrt{A^2 - 4B(1 - W)}}{2B} - A \tag{19}$$

For temperatures < 0°C, another method must be used. The first derivative of equation (12) is used to successively approximate *t*. This equation is

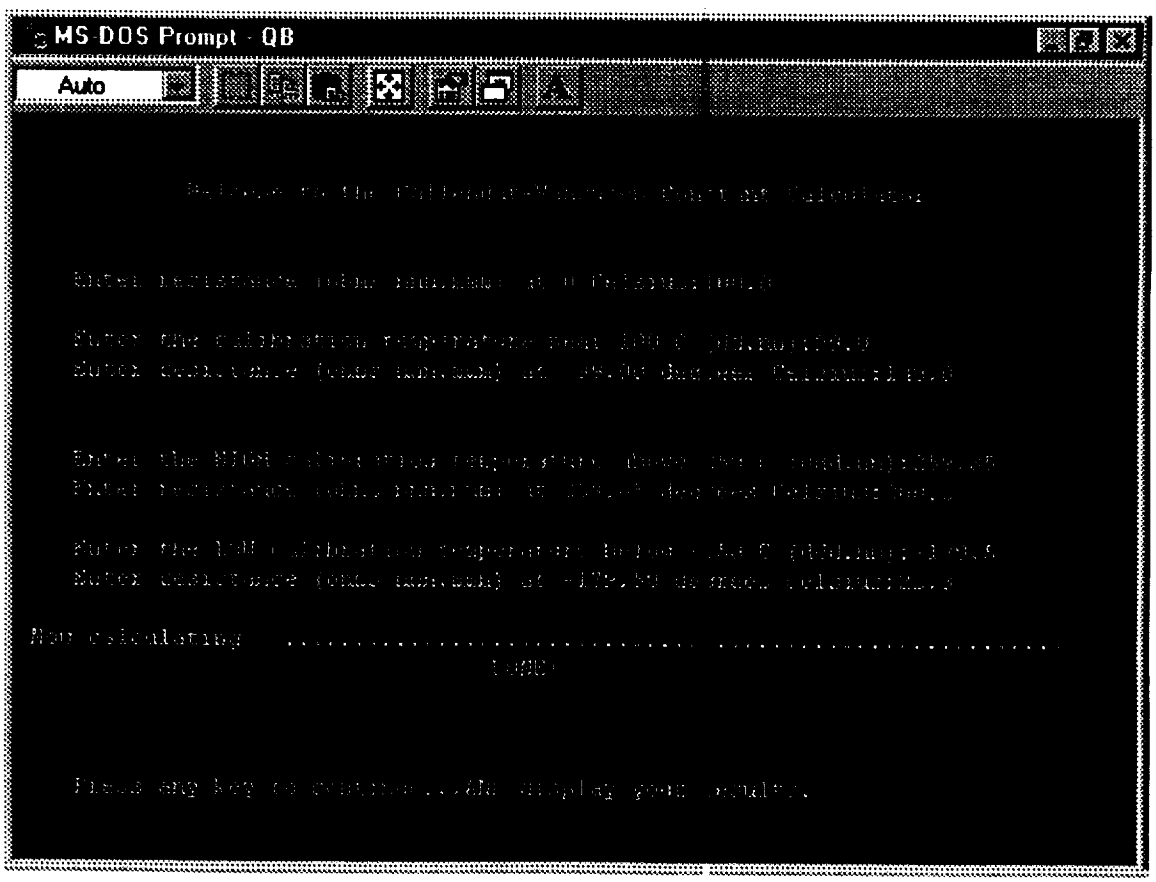
$$\frac{dW}{dt} = A + 2Bt + 4Ct^{2}(t - 75) \qquad (20)$$

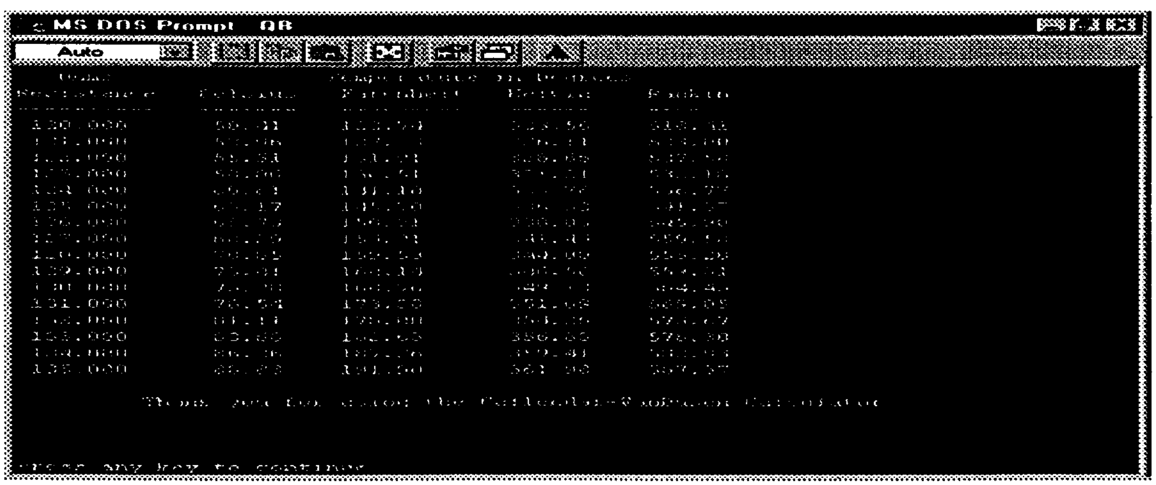
where C = 0 for t > 0°C

<u>Software Products for Using these Methods</u>

Software products were designed and created to help users of PRT data with the tasks of using the Callendar-Van Dusen method. Sample runs are illustrated in this report. The products are available from Mr. Bill White, Bldg. 4487, EB-22, Marshall Space Flight Center, Alabama 35812.; telephone (205) 544-6417; email: William.B.White@msfc.nasa.gov.

Sample Output





Acknowledgments

The author would like to acknowledge the assistance and guidance of NASA colleague William B. (Willie) White in this research. In addition, the entire team members of EB-22 (B Wing), especially Bobby Money, James Currie, Clint Patrick, and Branch Chief Joe Zimmerman helped acquaint me with the facilities and procedures of the laboratory and branch.

References

<u>Temperature Calibration and Interpolation Methods for Platinum Resistance Thermometers, Rosemount Report 68023F</u>, Rosemount Inc.